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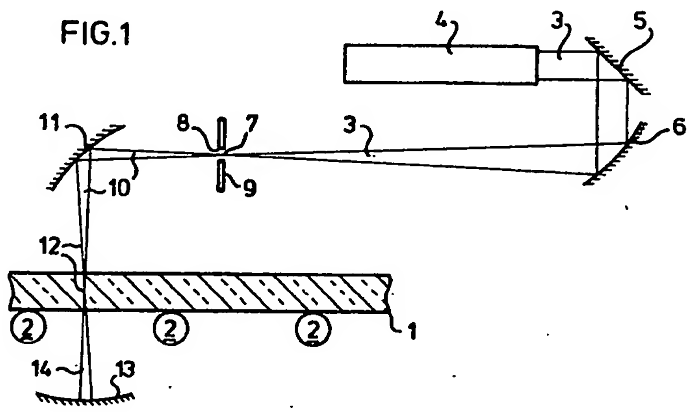
(58) Field of search
C1M
G2J

(54) Method and apparatus for cutting glass

(57) Vitreous material can be cut by scanning it with laser radiation along a desired path of fracture.

At least one beam (3) of laser radiation is directed through an aperture (8) in a screen (9) to modify the beam cross-section, so that when the modified beam (10) is incident at 12 on the path of fracture it has one or two apexes (cf 16) and the vitreous body (1) is scanned so that the or each apex points along the path of fracture.

FIG.1



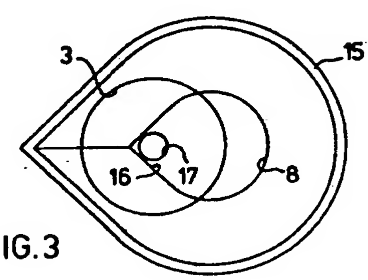


FIG.3

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FIG.1

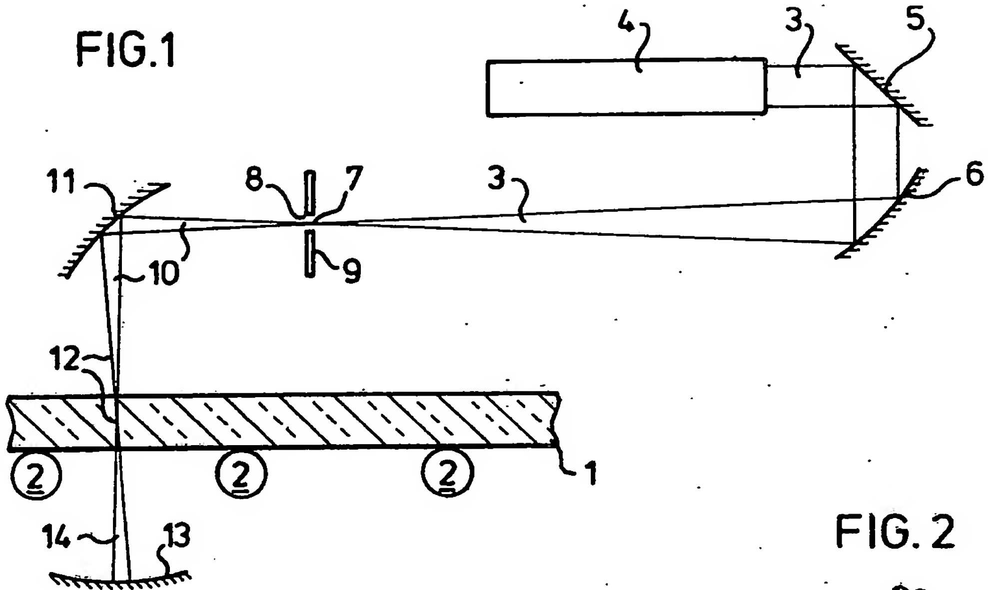
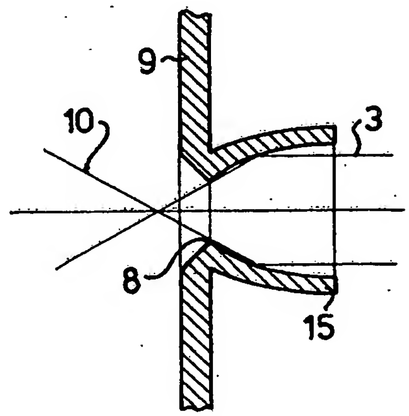


FIG. 2



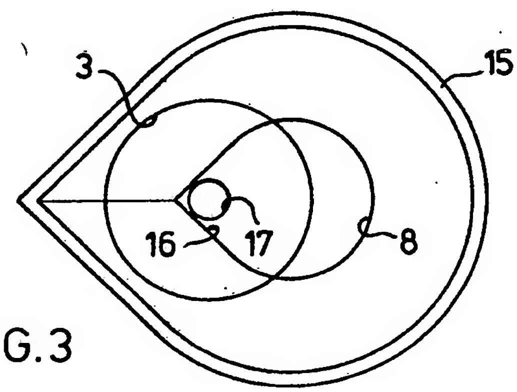


FIG.3

SPECIFICATION

Method and apparatus for cutting glass

This invention relates to a method of fracturing a body of vitreous material by scanning the body with laser radiation.

A principal field of use for such methods lies in trimming the edges of a continuous ribbon of freshly formed flat glass as it leaves in annealing lehr and before it is cut into sheets. When used in this way a static laser beam is focused on each margin of the ribbon a desired distance is from its edge so that the desired path of fracture is scanned as the ribbon is conveyed forwards. The edges of the ribbon break off due to thermal shock created in the glass by the absorption therein of the laser light energy. Use may also be made of a static or a moving laser beam for cutting a glass ribbon into sheets of for cutting sheets into smaller sheets.

It has been found that in many cases such methods do not result in a clean fracture and it is an object of the present invention to go at least some way towards remedying this defect.

According to the present invention there is provided a method of fracturing a body of vitreous material by scanning the body with laser radiation, characterised in that the or at least one beam of laser radiation is directed through an aperture in a screen to provide such beam(s) when incident on the path of fracture, with a cross-section having one or two apexes and in that the body is scanned so that the or each such apex points along the path of fracture.

Prior art methods rely on a laser beam or beams of unmodified cross-section. Such a beam will at any instant act to heat a substantially cylindrical portion of a body of vitreous material on which it is incident. When a cylindrical portion alone is heated it will be apparent that the stresses induced are uniformly distributed around the cylinder and there is no preferential breaking direction. Such concentration of the stress as there is in the prior art methods arises because the laser beam scans across the vitreous material and/or because the path of fracture is prescored. However, this is insufficient to ensure fracture of the vitreous material cleanly along the desired path. By adopting the present invention and modifying the cross-section of the or at least one laser beam so that it has one or two apexes pointing along the path of fracture and in no other direction, the induced stresses are strongly concentrated and act to fracture the vitreous material cleanly along the desired path.

A method according to the present invention is particularly suitable for fracturing vitreous material along a curved and/or irregular path.

Preferably, a central portion of such beam passes uninterrupted through said screen aperture to lie in an apical region of the modified beam cross-section. This promotes efficiency since the energy dissipated by a laser beam of unmodified cross-section has a greater flux density at its centre.

The flux density of the energy dissipated by the laser beam incident on the vitreous body can be further increased by adopting any one or more of the following preferred features:

i. the laser radiation is focused on the plane of the screen aperture;

ii. an image of the screen aperture is brought to a focus within the vitreous material;

iii. the screen is provided with a reflective cup surrounding its aperture which directs substantially all of said beam through said aperture.

In some embodiments of the invention the beam cross-section is modified to a lenticular shape having two apexes pointing in opposite directions along the path of fracture, but it is preferred that the beam(s) is or are provided with a cross-section having a single apex. In such a case it is preferable for the body to be scanned so that such single apex leads the beam cross-section along the path of fracture.

In the most preferred embodiments of the invention the wavelength of the laser radiation and the thickness and composition of the vitreous material are such that between 20% and 70% of the radiation incident on each side of the vitreous material is absorbed within its thickness. This has been found to promote a favourable compromise between uniformity of energy absorption throughout the thickness of the vitreous body and total energy absorption by the body and it also promotes rapid cutting due to direct absorption of radiation at different levels within the vitreous material being severed.

Advantageously, the wavelength of the laser radiation used lies in the range 2 μm to 6 μm inclusive. The absorption of radiation of such wavelengths by ordinary soda-lime glass is good for the purpose in view. In general, the longer the wavelength the greater is the coefficient of the absorption so that within that range longer wavelengths are best used for fracturing thinner glass and shorter wavelengths for fracturing thicker glass.

When acting in accordance with the present invention, it has been found unnessesary to pre-score the vitreous material with a cutting wheel or other scoring tool. Indeed such scoring is disadvantageous because it tends to create fissures across the path of fracture which are subsequently able to act as stress raisers in the vitreous material after cutting. It is accordingly preferred that said fracture is wholly attributable to thermal shock due to the absorption in the vitreous material of laser energy.

The present invention includes apparatus for fracturing a body of vitreous material comprising a support for the body, at least one laser light source and means for causing laser radiation emitted by the or each such light source to scan a body on said support, characterised in that a screen having an aperture is located in the path of the or at least one beam of laser radiation to impart to such beam a cross section having one or two apexes, the scanning means being so arranged that during scanning, the or each said apex points along the projected path of fracture.

Such apparatus preferably includes one or more of the following optional featurss:

i. means is provided for focusing such beam on the plane of said screen aperture.

ii. means is provided for focusing an image of said screen aperture on a vitreous body on said support.

iii. the screen is provided with a reflective cup surrounding its said aperture to direct substantially all of such beam through aperture.

iv. said aperture is shaped to impart to such laser beam a single apex.

v. it is preferred that the or at least one laser light source is a hydrogen fluoride—deuterium fluoride laser or a CO laser. This has the advantage that the wavelengths of the radiation emitted thereby are favourably absorbed by the vitreous material.

vi. the wavelength emitted by the or each laser light source lies between 2 μm and 6 μm inclusive; vii. means is provided for altering the wavelength of the laser radiation.

The wavelength of the laser radiation may for example be altered by making use of a dye laser or frequency shifting crystals as known in the art.

A preferred embodiment of the present invention will now be described in greater detail with reference to the accompanying drawings.

Figure 1 is a schematic diagram of apparatus according to the invention and

Figures 2 and 3 are respectively sectional and front views of beam cross-section modifying screen.

Figure 1 shows an embodiment of apparatus according to the invention for severing a glass sheet or ribbon 1 as it travels along supported by a conveyor 2. A laser beam 3 emitted by a laser light source 4 travels to first and second mirrors 5, 6. The first mirror 5 is a plane mirror, but the second mirror 6 is a concave mirror. The effect of these two mirrors 5, 6 is to reverse the direction of the laser beam 3 and focus it at 7 in the plane of an aperture 8 in a screen 9 where the cross-section of the beam is modified. The modified beam 10 continues to a second concave mirror 11 whence it is reflected through the glass sheet or ribbon 1 at a point 12 on the desired path of fracture. The second concave mirror 11 acts to focus the laser-projected image of the screen aperture 8 at that point. Any proportion of the laser radiation which is not absorbed by the sheet or ribbon 1 passes through the glass to an optional third concave mirror 13, e.g. a spherical mirror located so as to reflect that radiation 14 back and bring it to focus at the same point 12.

The mirrors used suitably bear a front-surface reflective coating, for example of gold or aluminium, so that as little laser energy is absorbed by them as possible.

The aperture 8 in the screen 9 is shown in Figures 2 and 3. The aperture is surrounded by a reflective cup 15 which is targeted by the laser beam 3 so that substantially all the laser radiation energy passes through the aperture 8. As shown in Figure 3, the aperture 8 is shaped with an apex 16 to modify the cross section of the beam 3 to the same shape, and the screen 9 is orientated so that the resulting apex of the modified beam 10 points along the desired path of fracture. When the thus modified beam 10 passes through the sheet or ribbon, the resultant energy absorption will stress the glass normally to the outline of the beam so that there will clearly be a high stress concentration at the laser-projected image of the apex 16 and the resultant stresses there will be at right angles to the desired path of fracture thus contributing to a clean fracture of the glass. That the image of the aperture 8 carried by the returning laser radiation 14 is reversed is not important because the image of the apex 16 will still be directed along the desired path of fracture, though in the opposite direction.

As shown in Figure 3, the beam 3 is aimed at the reflective cup 15 so that a central portion 17 of the beam 3 passes directly through the aperture 8 in the region of apex 16. Since such central beam portion 17 has the highest energy flux density this further contributes to a high stress concentration in the glass at the region of the projected image of the apex 16 thus further promoting a preferred fracture line in the glass along the desired path.

By this means it is possible, using for example a 4 to 5 watt laser to dissipate some 300 to 400 W/mm² in the glass being severed.

When severing ordinary soda lime glass it is recommended to use a laser emitting radiation in the 3-4 μm range when the glass is 3 mm thick. This results in absorption by the glass of about 50% of the energy incident on each side. For a similar energy absorption when severing very thin glass, e.g. glass less than 1 mm thick, it is suitable to use a laser light with a wavelength of about 5 μm.

The invention is also useful for cutting along lines which are other than straight, for example for cutting circular discs.

The use of the optional mirror 13 so that

coincident points on the line of severance are laser-irradiated from opposite sides is claimed in our copending application No 8313287 filed under Agents reference 262/VARISER.

CLAIMS

1. A method of fracturing a body of vitreous material by scanning the body with laser radiation, characterised in that the or at least one beam of laser radiation is directed through an aperture in a screen to provide such beam(s) when incident on the path of fracture with a cross-section having one or two apexes and in that the body is scanned so that the or each such apex points along the path of fracture.

2. A method according to claim 1 wherein a central portion of such beam passes uninterrupted through said screen aperture to lie in an apical region of the modified beam cross section.

3. A method according to claim 1 or 2 wherein the laser radiation is focused on the plane of said screen aperture.

4. A method of according to any preceding claim, wherein an image of the screen aperture is brought to a focus within the vitreous material.

5. A method of according to any preceding claim, wherein the screen is provided with a reflective cup surrounding it aperture which directs substantially all of said beam through said aperture.

6. A method according to any preceding claim, wherein the beam (s) is or are provided with a crosssection having a single apex.

7. A method according to claim 6 wherein the body is scanned so that such single apex leads the beam cross-section along the path of fracture.

8. A method according to any preceding claim wherein the wavelength of the laser radiation and the thickness and composition of the vitreous material are such that between 20% and 70% of the radiation incident on each side of the vitreous material is absorbed within its thickness.

9. A method according to any preceding claim, wherein the wavelength of the laser radiation used lies in the range 2 μm to 6 μm inclusive.

10. A method according to any preceding claim, wherein said fracture is wholly attributable to thermal shock due to the absorption in the vitreous material of laser energy.

11. Apparatus for fracturing a body of vitreous material comprising a support for the body, at least one laser light source and means for causing laser radiation emitted by the or each such light source to scan a body on said support, characterised in that a screen having an aperture is located in the path of the or at least one beam of laser radiation to impart to such beam a cross-section having one or two apexes, the scanning means being so arranged that during scanning, the or each said apex points along the projected path of fracture.

12. Apparatus according to claim 11 wherein means is provided for focusing such beam on the plane of said screen aperture.

13. Apparatus according to claim 11 or 12, wherein means is provided for focusing an image of said screen aperture on a vitreous body on said support.

14. Apparatus according to any of claims 11 to 13, wherein the screen is provided with a reflective cup surrounding its said aperture to direct substantially all of such beam through aperture.

15. Apparatus according to any of claims 11 to 14 wherein said aperture is shaped to impart to such laser beam a single apex.

16. Apparatus according to any of claims 11 to 15 wherein the or at least one laser light source is a hydrogen fluoride-deuterium fluoride laser or a CO laser.

17. Apparatus according to any of claims 11 to 16, wherein the wavelength emitted by the or each laser light source lies between 2 μm and 6 μm inclusive.

18. Apparatus according to any of claims 11 to 17, wherein means is provided for altering the wavelength of the laser radiation.

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